DOCUMENT RESUME

ED 236 055 SE 043 403

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TITLE Relationships between Cognition of Teachers and Quality of Teaching Style in Elementary Science.
PUB DATE May 83
NOTE 19p.; Paper presented at the Congress of the Australian and New Zealand Association for the Advancement of Science (53rd, Perth, Australia, May 1983).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Development; *Developmental Stages; Elementary Education; *Elementary School Science; Higher Education; *Preservice Teacher Education; Science Education; *Science Instruction; Teacher Behavior; *Teaching Styles
IDENTIFIERS *Australia (Western Australia); Science Education Research

ABSTRACT

This study is concerned with preservice primary school teachers (N=100), a group of tertiary students who traditionally come from the secondary school stream. These students have, on the whole, avoided subjects like physics, chemistry, and mathematics that demand a high level of cognitive development for understanding/assimilation of abstract concepts. The study focuses on the cognitive developmental levels of these individuals on leaving the training institution and considers implications for elementary science by sampling science teaching styles. Results indicate that final year students in the transitional stages of cognitive development exhibit teaching behaviors in elementary science lessons of a higher quality than those who are in concrete or formal operational stages. This suggests that concrete operational students entering teacher preparation programs must be identified and given opportunities to develop to higher cognitive levels. Formal operational students constitute a different problem. These students are undoubtedly capable of conducting lessons of a high cognitive level but appear to lack understanding of the intellectual problems facing children, probably because they cannot relate to problems of abstract reasoning not encountered by themselves. Since both concrete and formal students tend to conduct less practical, "hands-on" science lessons than transitional students, strategies fostering such teaching methods need to be considered. (JN)

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RELATIONSHIPS BETWEEN COGNITION OF TEACHERS AND QUALITY OF TEACHING STYLE IN ELEMENTARY SCIENCE.

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PERTH

MAY, 1983

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The massive injection of funds, by the United States Government, into school science projects that followed the launching of Sputnik 1 is now history. Suffice it to say that what followed was unprecedented ferment in the design of science curricula. Unfortunately what is now evident, is that many of the secondary school programs that resulted emphasised the accuracy of the discipline's structure but failed to take cognizance of the intellectual capacity of the child to cope with the tasks (Marek, 1981).

The primary science programs that were developed in the same era were better conceived from the stand point of matching the learning to the intellectual level of the child. Programs like SCIS, ESS S-APA and the Nuffield scheme emphasised an inquiry "hands on" approach and demonstrate an obvious influence of the Piagetian theory of childrens intellectual development through concrete experiences to an abstract reasoning level.

In spite of the early promises of the inquiry approach the objectives of these primary science curricula have not been achieved in Great Britain (Department of Education and Science, 1978), the United States (De Rose, Lockard and Paldry, 1979) and Australia (Varley, 1975 and Knight, 1970). The reason, or so it would appear, is the failure of primary school teachers to provide practical experiences in science which afford the child the opportunity to inquire.

Could it be that the large proportion of teachers who demonstrate a science teaching style not conducive to inquiry skill development are

themselves lacking in intellectual development to the extent that they have not reached the formal operation stage as defined by Inhelder and Piaget. (1958)?

That the formal operational stage of cognitive development has important application for science education is apparent from the increasing number of studies on this topic reported in recent literature. Gabel (1979) notes that in the year 1977, the number of such studies exceeded those in the previous four-year period. Literature reviews carried out by Chiapetta (1976) and Gabel (1979) listed numerous studies applicable to science learning but none that were concerned with the intellectual level of teachers and what the implications might be for science teaching. Chiapetta reviewed ten studies concerned with the cognitive level of adolescents and young adults. Many of these involved the measurement of teacher education students on entry to the training institution. Strangely, not any measured the cognitive level of students on leaving the institution to take up teaching positions.

The present study is concerned with preservice primary school teachers, a group of tertiary students who traditionally come from the secondary school stream that has, on the whole, avoided subjects like physics, chemistry and mathematics that demand a high level of cognitive development for the understanding and assimilation of abstract concepts. The study focuses on the cognitive developmental levels of prospective primary school teachers on leaving the training institution and considers the implications for elementary science by sampling science teaching styles.

Procedure

Instruments

The Piagetian Task Instrument (P.T.I.) (McKenna, 1982), was used to measure the cognitive developmental level of the sample. The P.T.I. consisted of five interview tasks, Stickmen (Karplus & Peterson, 1970), Bending Rods, Inclined Plane, Coloured Chemicals and Projection of Shadows (Inhelder and Piaget, 1958). The tasks were selected to obtain a measure of formal reasoning containing the essential components identified by Inhelder and Piaget (1958). Total scores on the P.T.I. were used to categorise students into three groups according to the number of tasks they correctly solved. (Formal Operational - 4 to 5 tasks correctly solved, Transitional Operational - 2 to 3 tasks correctly solved and Concrete Operational - 0 to 1 tasks correctly solved.) As all of the five tasks were used by either Inhelder and Piaget (1958) or their collaborators the P.T.I. was judged to have high content validity. Construct validity was investigated by factor analysis. The correlations obtained ranged from 0.38 to 0.77 indicating a strong underlying trait hereafter referred to as cognitive development. Reliability was investigated using generalizability theory (Cronbach, 1972). A generalizability coefficient of 0.68 analogous to a Cronbach coefficient was obtained.

A modified form of the Science Lesson Analysis System, SLAS (Hacker 1982) was used to determine the Science Teaching style of the sample. SLAS enables an observer to sample class room interactions and score them on a score sheet made up of nine columns of verbal and non verbal "interactions" and twelve rows of "purposes" for the interaction, giving in all 108 cells of class room behaviour. In the current research small groups of children were used and the lesson recorded on audio tapes which, in conjunction with

lesson plans, were later scored by two trained observers. Twenty one variables were obtained by summing "percentage uses" of the cells by rows (types of interactions) and summing cells by columns (purposes for interactions). A further seven variables were obtained by adding some related rows and some related columns. Coefficients of inter rater agreement were calculated for the two observers used. The coefficients ranged from 0.54 to 1.00 and were considered satisfactory. Evidence of the content and construct validity of SLAS is described by McKenna (1982). Reliability was investigated for each of the 28 variables using a generalisability coefficient formula used by Tobin and Copie (1980). According to Cardinet et al (1979) coefficients of less than 0.8 should be accepted with caution. In the present instance thirteen of the coefficients were of the magnitude 0.8 and above, seven were marginal and one, row 5 - solving problems by applying abstractions etc., could not be calculated due to extremely low usage of the categories in this row.

Data

The participants in the study were 100 primary teacher education students who were completing their final year of study at the Mount Lawley CAE in 1978. The teaching style data were collected during a three months simulated teaching experience in primary schools between May and August which was undertaken with groups of 8 children (4 boys and 4 girls). The grade of the children used and the lesson topic were chosen by the student. Each lesson was of thirty minutes duration. The lesson was recorded on audio tape and accompanied by a lesson outline. The P.T.I. was administered by the author and ten team members who were staff of the College and trained by the author. An inter-rater agreement coefficient of 0.98 was obtained when the team assessed a taped interview. Students were randomly assigned

to the team members. The interviews took place between October and December, 1979. The scores obtained by the students are shown in Table 1.

------- Table 1 about here ----------

Analysis

The students were divided into three groups according to their cognitive developmental level. ANOVA was used to test differences in group means on each of the 28 teaching style variables. In each case an omega squared value was computed as a measure of the variance in the dependent variable attributable to the independent variable. If the magnitude of F was statistically significant (ie $p < .05$), orthogonal contrasts were used to determine whether : 1. The group mean was different from the average attained by groups one and three, and 2. The group one mean was different from the group three mean.

A sign test (Siegel, p. 68-75, 1956) was used to measure the strength of a trend whereby one cognitive developmental group demonstrated a higher quality teaching behaviour on most of the teaching style variables.

Results

The means compared in 28 analyses of variance with each teaching style variable as the dependent variable are summarized in Table 2. below.

------- Table 2 about here --------

Accepting that a probability of less than 0.05 is too small to accept differences as being due to chance, the null hypothesis was rejected in four cases where statistically significant F values were obtained. The

results are shown in Tables 3, 4, 5 and 6 below.

------ Table 3. about here ---------

For the variable "Pupil interaction with multi media materials", results in Table 3. indicate the rejection of the null hypothesis. The planned orthogonal contrast indicated that the mean for the transitional group was significantly less than the average of the other two groups. The difference between the Concrete and Formal groups was not significant.

------- Table 4. about here --------

------- Table 5. about here --------

-------- Table 6. about here --------

For each of the results in Tables 4, 5 and 6 the planned orthogonal contrast indicated that the mean for the transitional group was significantly more than the average of the other two groups. The dependent variables concerned were "Pupil interaction with science materials", "Pupil/Teacher interaction with science materials" and "Verbal purposes for interaction-Process". In each case the difference between the concrete and formal groups was not significant.

Table 2 indicates a trend for group two (transitional) to demonstrete higher mean scores on desirable teaching style categories and lower mean scores on undesirable categories for 24 of the 28 teaching style variables. The sign test that was conducted confirmed the significance of the trend ($Z = 5.68$, $p < 0.001$).

Discussion

Group 2 students, transitional in their cognitive developmental level, appear to conduct less science lessons where the children are involved in activities requiring reference to books, films, pictures, charts, chalk boards and the like. The children are however more involved with practical science materials. Further, the transitional teacher does more demonstrating with practical science materials. The children in the classes of the transitional teacher appear to be using more process skills. They are involved in inferring, hypothesizing, observing, identifying, describing, designing and interpreting.

There is also a significant tendency for transitional teachers generally to differ from their peers in the degree to which they demonstrate teaching behaviours accepted as desirable by modern science educators.

Implications

From this study it appears that final year students who are in the transitional stages of cognitive development, exhibit teaching behaviours in elementary science lessons of a higher quality than those who are in the concrete and formal operational stage. The implications for training institutions are quite clear. Concrete operational students entering the institution must be identified and given every opportunity to develop to higher cognitive levels. Using a sample of university students, Renner and Lawson (1975) were able to demonstrate significant gains in formal thinking abilities when the curricula materials and problems were concrete in nature. The students of formal operational level constitute a different problem. These students are undoubtedly capable of conducting lessons of a high cognitive level but appear to lack understanding of the intellectual problems facing

the children; probably because they cannot relate to problems of abstract reasoning not encountered by themselves. Recent changes in the science education program at the College may correct this deficiency also. Currently emphasis is placed on the importance of strategy analysis in the preparation of science lessons (Tobin 1982). Each student is now required to prepare a number of lessons and perform them in front of a video camera. Video tapes are then scored by the students themselves as well as being viewed and commented on by the students' peers.

If the sample of pre-service primary school teachers is a reflection of a similar population among practising primary school teachers, then implications for science learning and indeed any studies requiring abstract reasoning could be serious indeed. The present research has suggested that the more concrete and the more formal operational teachers tend to conduct less practical, "hands on" material-centred science lessons. The literature suggests that such experiences are necessary to facilitate the development of formal operational thinking. Renner (1976) warns that, "... concrete students who are required to interact with formal content do not achieve increased intellectual development". Renner and Lawson (1975) reporting that 40%-60% of adults fail to acquire abstract reasoning abilities, support the view that at least some of the lack of intellectual capabilities can be traced to inappropriate instructional strategies.

The present study also has implications for secondary education. According to McKinnon and Renner (1971), recent research leads to the hypothesis that the ".... secondary educational experience does not now promote logical thinking in most students.....". Nor should it, for now the unfortunate pupil who is still at the concrete operational level is confronted with

a group of teachers who, having successfully completed degrees in science and mathematics are most likely to be highly formal operational themselves If such teachers at this level tend to neglect concrete experiences for their pupils, and the present research suggests they might, then the provision of school science experiences to promote the development of formal reasoning ability, is far from satisfactory.

The findings of this research suggest that the student teachers in the transitional stage of cognitive development perform the best on accepted science teaching style categories. This however, must not blind us to the real situation. The transitional teachers, after all, solved as few as two formal reasoning tasks out of five. They are still disadvantaged in teaching science. The optimal situation to be aimed for is obviously teachers operating at the formal operational level and using high quality teaching styles. The reality of the situation is that no matter how well the teacher training institutions conduct programs to raise the cognitive level of transitional students and develop strategy analysis programs to increase the sensitivity of future teachers to the reasoning problems of children, a significant proportion of concrete operational teachers will continue to enter the schools. It is these teachers who will, unfortunately, contribute to the production of future generations of children "handicapped" like themselves.

TABLE 1

Scores obtained by the sample (N = 100) on the P.T.I

No. of Item Correct	Category	No. of Students	Percentage
0-1	Concrete	28	28%
2-3	Transitional	42	42%
4-5	Formal	30	30%

TABLE 2

Mean scores on 28 science teaching variables for three cognitive development groups

	VARIABLES	GROUP MEANS		
ROWS	PURPOSE OF THE INTERACTION	1	2	3
1	Acquiring, recalling or confirming facts	234	207	209
2	Delineating scientific concepts, principles or theoretical models	15	3	24
3	Identifying problems	23	27	30
4	Solving concrete problems	88	95	110
5	Solving problems by applying scientific concepts, principles or models	0	·9	·3
6	Making or testing hypothesis or speculation	36	57	31
7	Identifying or describing apparatus, equipment or materials	14	28	25
8	Describing or practising conventional experimental procedures	175	220	206
9	Designing novel experimental procedures	29	36	17
10	Making, describing or recording observations	319	389	345
11	Interpreting observed or recorded data	50	68	56
12	Inferring from observed or recorded data	11	14	10
COLUMNS	VERBAL INTERACTION			
1	Teacher talk (questions)	147	156	148
2	Teacher talk (statements)	163	191	160
3	Teacher talk (directives)	95	103	91
4	Pupil talk (to teacher)	72	90	82
5	Pupil talk (to each other)	99	111	120
COLUMNS	NON-VERBAL INTERACTION			
6	Teacher (science materials)	86	130	104
7	Pupil (science materials)	191	268	212
8	Teacher (multi media materials)	40	36	44
9	Pupil (multi media materials)	100	62	103
ROWS	COMPOSITE VARIABLES (ROWS)			
1 - 5	Product	361	335	374
6 -12	Process	637	816	694
6,9,12	Creativity	77	109	60
COLUMNS	COMPOSITE VARIABLES (COLUMNS)			
1 - 3	Teacher talk	407	451	400
4 - 5	Pupil talk	172	202	202
6 - 7	Teacher/Pupil use of Science Materials	278	399	316
8 - 9	Teacher/Pupil use of Multi Media Materials	141	98	148

TABLE 3

An analysis of variance to investigate differences in Pupil interaction with multi media materials (non verbal, C9) attributable to cognitive developmental level group

Source of variation	df	Sums of squares	F	P
Cognitive developmental level group	2	40007.60	4.09	.02
Residual	99	483924.91		

Omega-squared:
A-priori contrasts

Contrast	T-value	df	p
$\bar{X}_2 - \frac{(\bar{X}_1 + \bar{X}_3)}{2}$	- 2.98	94.5	.004
$\bar{X}_1 - \bar{X}_3$	- 0.18	52.7	.858

TABLE 4

An analysis of variance to investigate differences in Pupil interaction with science materials (non verbal, C7) attributable to cognitive developmental level group

Source of Variation	df	Sums of Squares	F	p
Cognitive developmental level group	2	115517.47	3.46	.04
Residual	99	1650589.9941		

Omega-squared:
A-priori contrasts

Contrast	T-values	df	p
$\bar{X}_2 - \frac{(\bar{X}_1 + \bar{X}_2)}{2}$	2.58	99.0	.01
$\bar{X}_1 - \bar{X}_3$	-0.61	99.0	.55

TABLE 5

An analysis of variances to investigate differences in combined Teacher/Pupil interaction with science materials (non verbal, $C_6 + C_7$) attributable to cognitive developmental level group

Source of Variation	df	Sums of Squares	F	p
Cognitive developmental level group	2	273738.73	3.08	.05
Residual	99	4397414.18		1

Omega-squared:
A-priori contrasts

Contrasts	T-value	df	p
$\bar{X}_2 - \frac{(\bar{X}_1 + \bar{X}_2)}{2}$	2.40	99	.02
$\bar{X}_1 - \bar{X}_3$	- .70	99	.49

TABLE 6

An analysis of variance to investigate differences in "Process" purposes for interactions ($R_6 + R_7$----R_{12}) attributable to cognitive developmental level

Source of Variation	df	Sums of squares	F	p
Piagetian Group	2	603583.10	3.25	.04
Residual	99			

Omega-Squared:

A - Priori Contrasts

Contrast	T-Value	df	p
$\bar{X}_2 - \frac{(\bar{X}_1 + \bar{X}_3)}{2}$	2.47	99	.02
$\bar{X}_1 - \bar{X}_3$	-0.72	99	.47

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